

## VERDIGRIS BASIN TOTAL MAXIMUM DAILY LOAD

**Waterbody: West Creek**  
**Water Quality Impairment: Dissolved Oxygen**

### 1. INTRODUCTION AND PROBLEM IDENTIFICATION

**Subbasin:** Upper Verdigris

**County:** Greenwood

**HUC 8:** 11070101

**HUC 11 (HUC 14s):** **020** (010, 020 and 030)

**Drainage Area:** 123.2 square miles

**Main Stem Segment:** WQLS: 17 (West Creek) starting at confluence with Verdigris River and traveling upstream to headwaters in north-central Greenwood County (**Figure 1**).

**Tributary Segments:** WQLS: Slate Creek (25)  
Onion Creek (23)

**Designated Uses:** Expected Aquatic Life Support, Secondary Contact Recreation and Food Procurement for Main Stem Segment and Tributary Segment 25 (Slate Creek).

Expected Aquatic Life Support and Secondary Contact Recreation on Tributary Segment 23.

**1998 303(d) Listing:** Table 1 - Predominant Non-point Source and Point Source Impacts

**Impaired Use:** Expected Aquatic Life Support

**Water Quality Standard:** Dissolved Oxygen (DO): 5 mg/L (KAR 28-16-28e(c)(2)(A))

### 2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

**Level of Support for Designated Use under 1998 303(d):** Not Supporting Aquatic Life

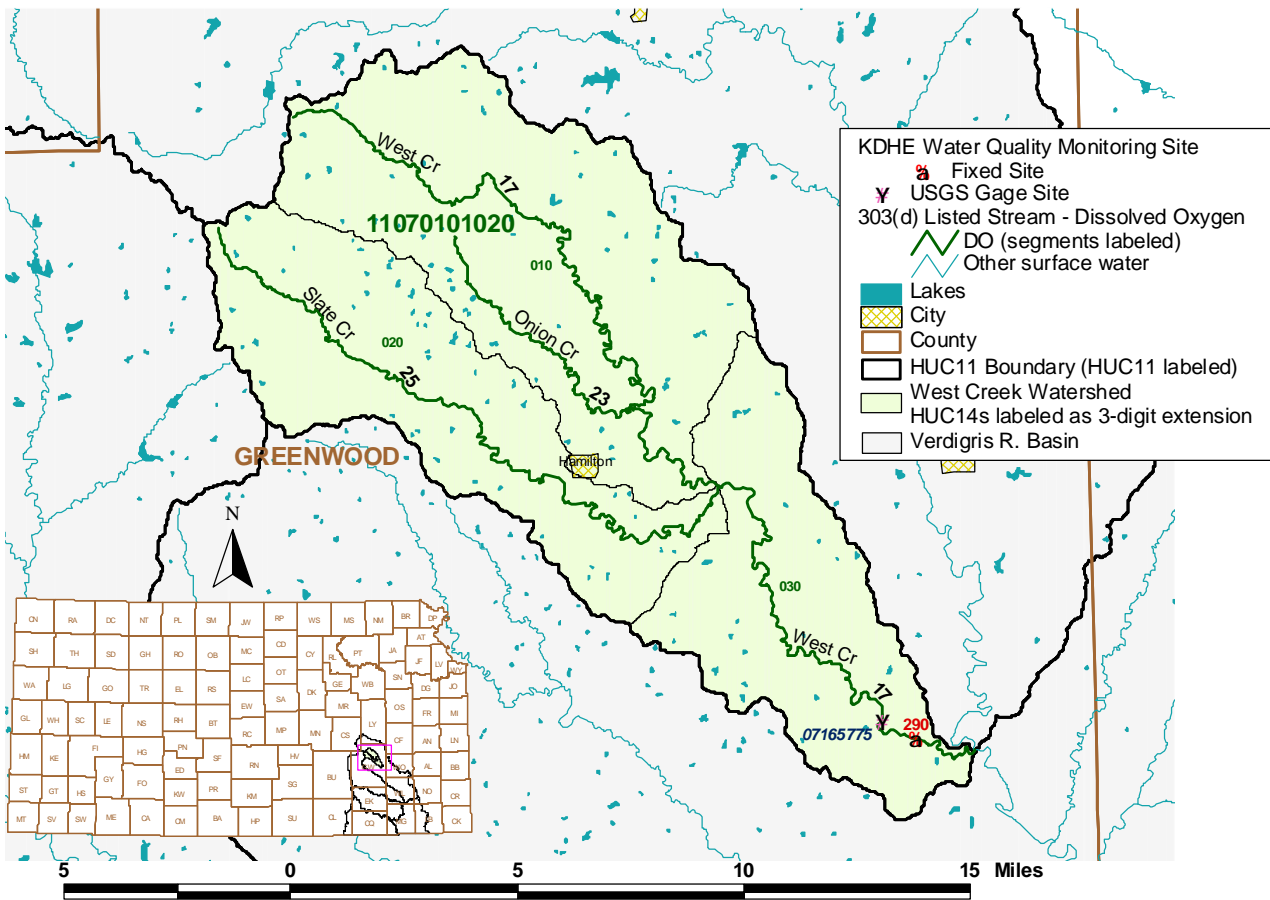
**Monitoring Sites:** Station 290 near Quincy

**Period of Record Used:** 1985-2001 for Station 290 (**Figure 2**)

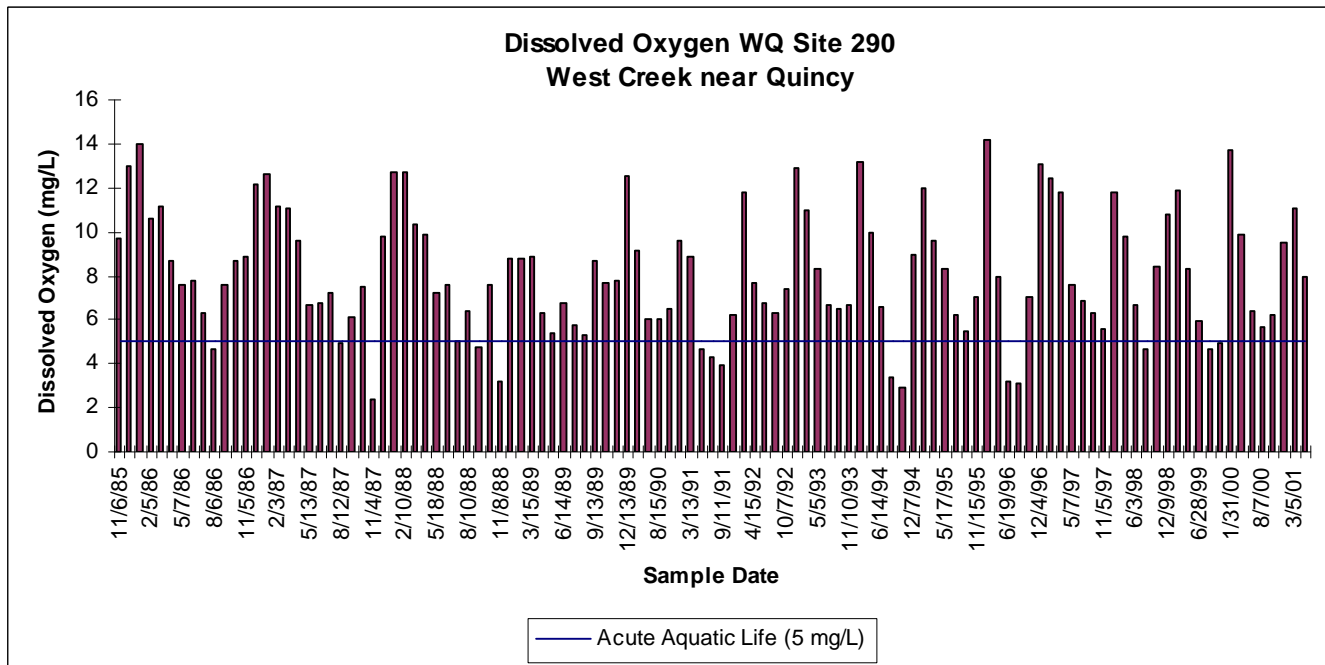
**Flow Record:** Otter Creek at Climax (USGS Station 07167500) matched to West Creek watershed (USGS 07165775).

**Long Term Flow Conditions:** 10% Exceedance Flows = 144 cfs, 95% = 0 cfs

## West Creek Watershed Dissolved Oxygen TMDL HUC and Stream Segment Map



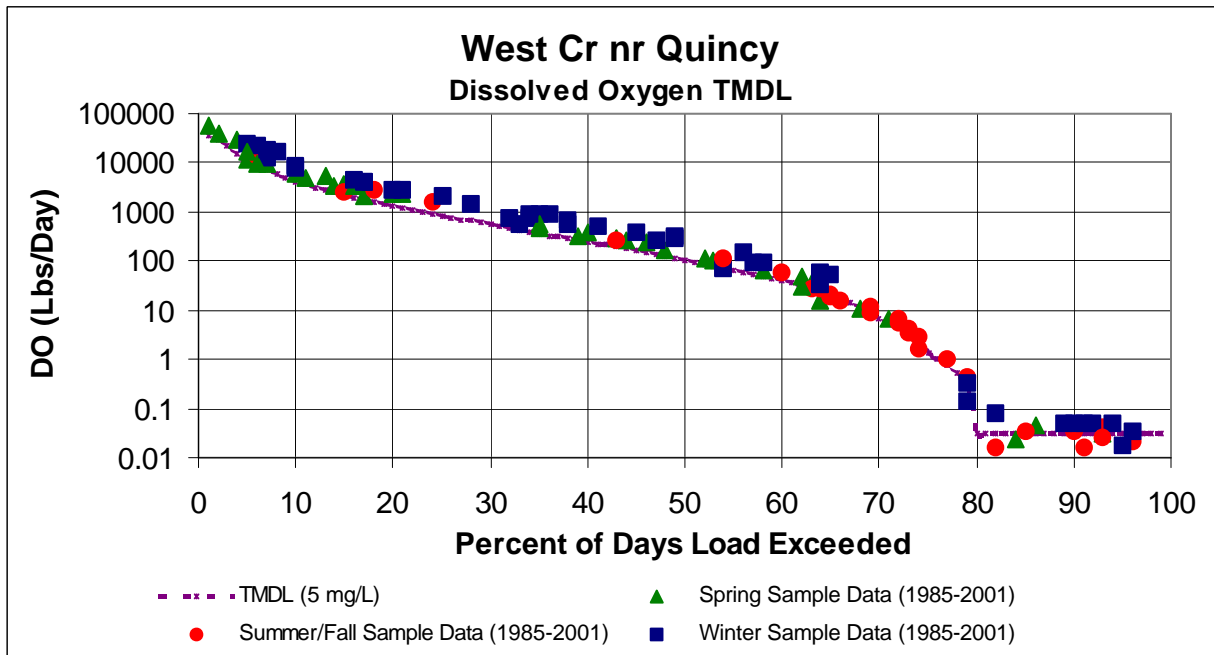
**Figure 1**



**Figure 2**

**Current Conditions:** Since loading capacity varies as a function of the flow present in the stream, this TMDL represents a continuum of desired loads over all flow conditions, rather than fixed at a single value. Sample data for the sampling site were categorized for each of the three defined seasons: Spring (Apr-Jul), Summer-Fall (Aug-Oct) and Winter (Nov-Mar). High flows and runoff equate to lower flow durations; baseflow and point source influences generally occur in the 75-99% range. Load curves were established for the Aquatic Life criterion by multiplying the flow values for West Creek near Quincy along the curve by the applicable water quality criterion and converting the units to derive a load duration curve of pounds of DO per day. This load curve graphically displays the TMDL since any point along the curve represents water quality at the standard at that flow. Historic excursions from water quality standards (WQS) are seen as plotted points *below* the load curves. Water quality standards are met for those points plotting *above* the applicable load duration curves (**Figure 3**).

Excursions were seen in all three defined seasons and are outlined in Table 1. Thirty one percent of the Summer-Fall samples and 8% of Spring samples were below the aquatic life criterion. Seven percent of the Winter samples were under the aquatic life criterion. Overall, 13% of the samples were under the criterion. This would represent a baseline condition of partial-support of the impaired designated use.



**Figure 3**

No DO violations have been encountered at flows exceeding 2.7 cfs on West Creek near Quincy, therefore a critical low flow can be identified on West Creek as those flows of 2.7 cfs or less.

**Table 1**  
**NUMBER OF SAMPLES UNDER DISSOLVED OXYGEN STANDARD OF 5 mg/L BY FLOW**

Station	Season	0 to 10%	10 to 25%	25 to 50%	50 to 75%	75 to 90%	90 to 100%	Cum Freq.
West Creek near Quincy (290)	Spring	0	0	0	2	1	0	3/39 = 8%
	Summer	0	0	0	5	1	3	9/29 = 31%
	Winter	0	0	0	1	1	1	3/45 = 7%

A watershed comparison approach was taken in developing this TMDL. The Otter Creek watershed (Water Quality Sampling Site 574 in the watershed was not impaired by low DO) has similar land use characteristics (see **Table 2 in Appendix**) to the Walnut Creek watershed, is of similar size and is located south of the West Creek watershed in the Verdigris River Basin. The relationship of DO to ammonia, biochemical oxygen demand (BOD), fecal coliform bacteria (FCB), water temperature, turbidity, nitrate, phosphorus, pH and total suspended solids (TSS) were used in the comparison.

**Table 3 in the Appendix** outlines those water quality data for the samples taken on the same day for the two sites of interest. **Table 4 in the Appendix** is a subset of Table 3 that summarizes

those sample dates when DO was below the aquatic life criterion for sample site 290. From Table 4 at site 290 the average ammonia, BOD, FCB, water temperature, turbidity, nitrate, phosphorus, pH, and TSS were similar to comparison site 574. In the case of BOD, the average in Table 4 was actually lower at site 290 than reference site 574. For three of these comparison dates (9/11/91, 6/19/96 and 8/5/98), even the reference site experienced low DO, although the magnitude of impairment was less at reference site 574.

In addition to the comparison provided in Table 4, there were samples dates (see **Table 5 in Appendix**) at site 290 in Table 3 when the flow was within the critical flow range yet DO was not violated. A comparison of site 290 averages between Tables 4 and 5 shows little difference between Tables 4 and 5. This indicates that the naturally driven factor of lower flow is likely the primary factor influencing the DO violations.

### **Desired Endpoints of Water Quality at Site 290 over 2007 - 2011**

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standard of 5 mg/l to fully support Aquatic Life.

Seasonal variation is accounted for by this TMDL, since the TMDL endpoint is sensitive to the low flow conditions, usually occurring in the Summer and Fall seasons.

This endpoint will be reached as a result of expected, though unspecified, improvements in tributary buffer strip conditions which will filter sediment before reaching the stream and stream morphology assessments which will be used to determine if enhancement to reaeration of flow within the stream is needed. Improvements to buffer strip conditions will result from implementation of corrective actions and Best Management Practices, as directed by this TMDL. Achievement of this endpoint will provide full support of the aquatic life function of the creek and attain the dissolved oxygen water quality standard.

Since BOD is not considered a factor in the occasional DO excursion at this site, the BOD target will be to maintain the historical average in stream BOD of 3.1 mg/L or less at the sampling site.

### **3. SOURCE INVENTORY AND ASSESSMENT**

**NPDES:** There is one NPDES permitted wastewater discharger within the watershed (**Figure 4**). This system is outlined below in **Table 6**.

**Table 6**

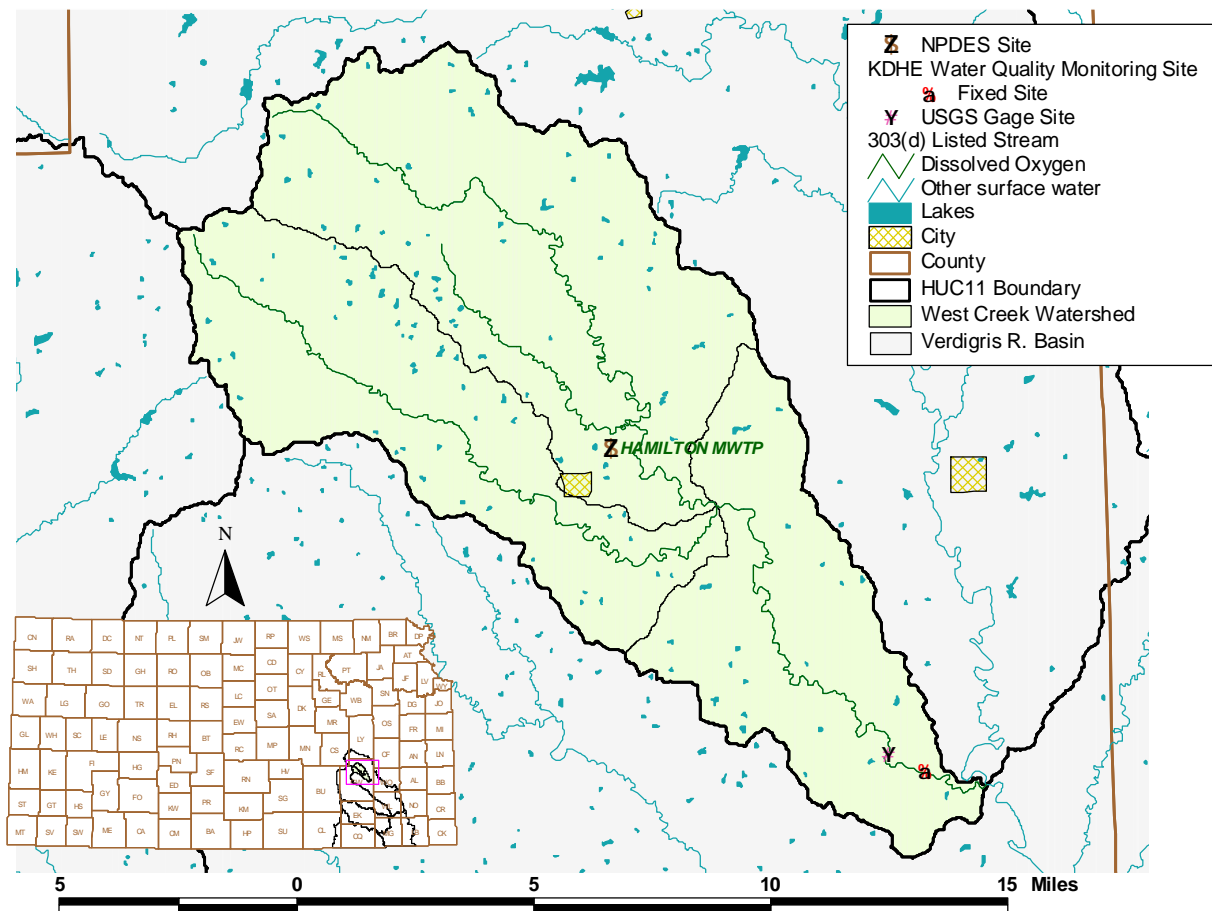
<b>DISCHARGING FACILITY</b>	<b>STREAM REACH</b>	<b>SEGMENT</b>	<b>DESIGN FLOW</b>	<b>TYPE</b>
Hamilton WTP	Onion Creek	23	0.033 mgd	Lagoon

The population projection for the city of Hamilton to the year 2020 indicates slight increase. Projections of future water use and resulting wastewater appear to be within the design flows for

of the current system's treatment capacity. Examination of 1998, 1999, 2000 and 2001 effluent monitoring of the city of Hamilton indicates that BOD is usually within permit limits during the critical months concern in this watershed. The city of Hamilton is presently under a schedule of compliance to achieve their final permit limitations (including BOD) by November 1, 2005.

**Livestock Waste Management Systems:** There are no livestock operations registered, certified or permitted within the watershed.

## West Creek Watershed NPDES Site



**Figure 4**

**Land Use:** Most of the watershed is grassland (91% of the area), cropland (5%), or woodland (3%). The cropland appears to be located primarily near the main stem and listed tributaries. The grazing density estimate is average across the watershed when compared to densities elsewhere in the Verdigris Basin (34-36 animal units/mi<sup>2</sup>) (**Figure 5 or Table 2 in Appendix**).

# West Creek Watershed Land Use, Population and Grazing Density

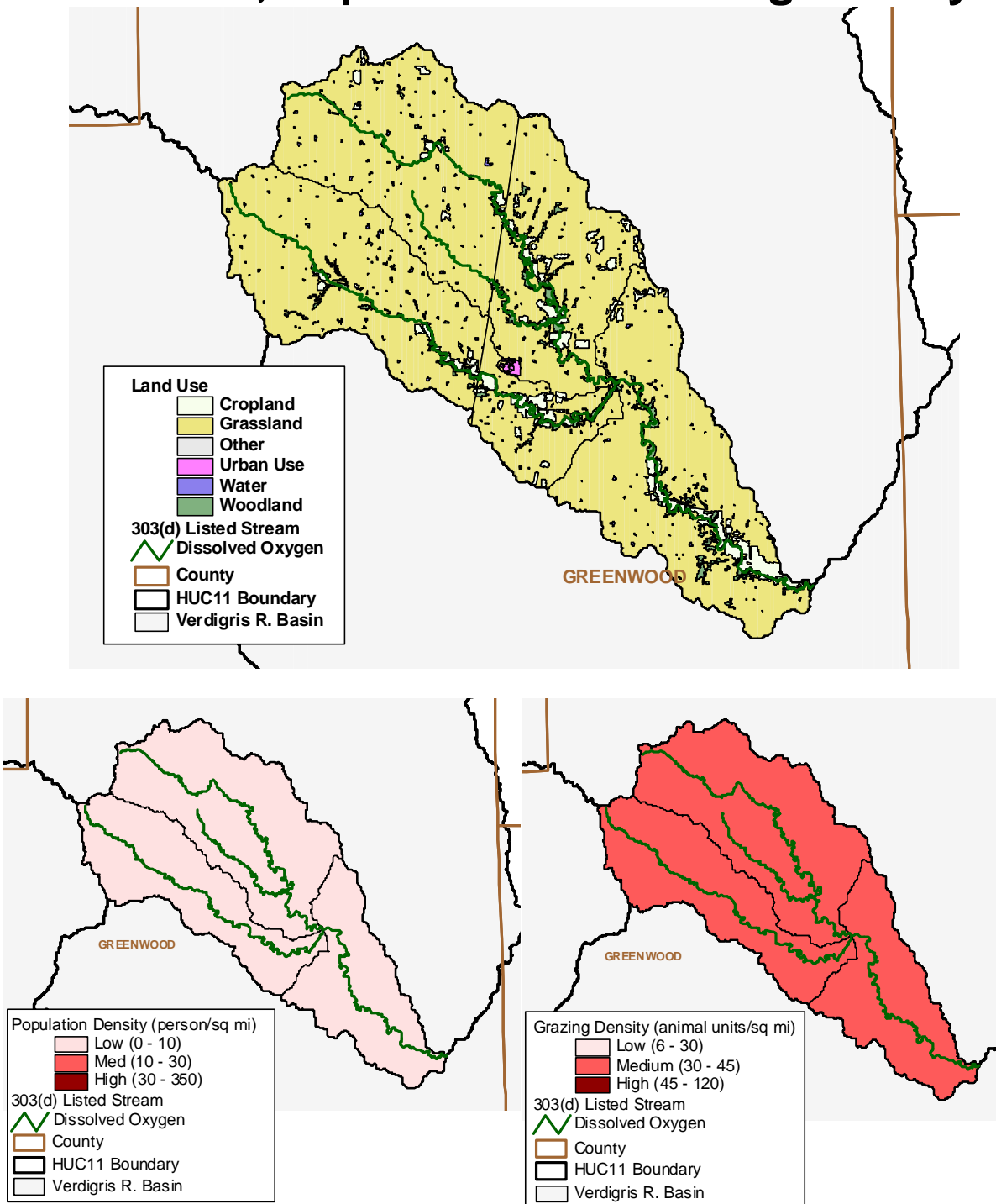


Figure 5

**On-Site Waste Systems:** The watershed's population density is low across the watershed when compared to densities across the Verdigris Basin (2 - 4 person/mi<sup>2</sup>) (**Figure 5**). The rural population projections for Greenwood county through 2020 indicate modest growth (28% increase). While failing on-site waste systems can contribute oxygen demanding substance loadings, their impact on the impaired segments is generally limited, given the small size of the rural population and magnitude of other sources in the watershed.

**Contributing Runoff:** The Walnut Creek watershed's average soil permeability is 0.5 inches/hour according to NRCS STATSGO data base. Practically all of the watershed produces runoff even under relatively low (1.71"/hr) potential runoff conditions (99.7%). Under very low (1.14"/hr) potential conditions, this potential contributing area is reduced to about 94%. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.57"/hr of rain will still generate runoff from 82% of this watershed.

**Background Levels:** Some organic enrichment may be associated with environmental background levels, including contributions from wildlife and stream side vegetation, but it is likely that the density of animals such as deer is fairly dispersed across the watershed and that the loading of oxygen demanding material is constant along the stream. In the case of wildlife, this loading should result in minimal loading to the streams below the levels necessary to violate the water quality standards. In the case of stream side vegetation, the loading should be greater toward the two thirds of the watershed with it larger proportion of woodland located near the main stem and tributaries.

#### **4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY**

BOD is a measure of the amount of oxygen required to stabilize organic matter in a stream. As such, BOD is used as a benchmark measure to anticipate DO levels while it measures the total concentration of DO that will be demanded as organic matter degrades in a stream. It is presumed that the maintenance of historical BOD loads with improvements to tributary buffers and any stream restoration projects cited by local assessments will reduce DO excursions under certain critical flow conditions. Therefore, any allocation of wasteloads and loads will be made in terms of BOD.

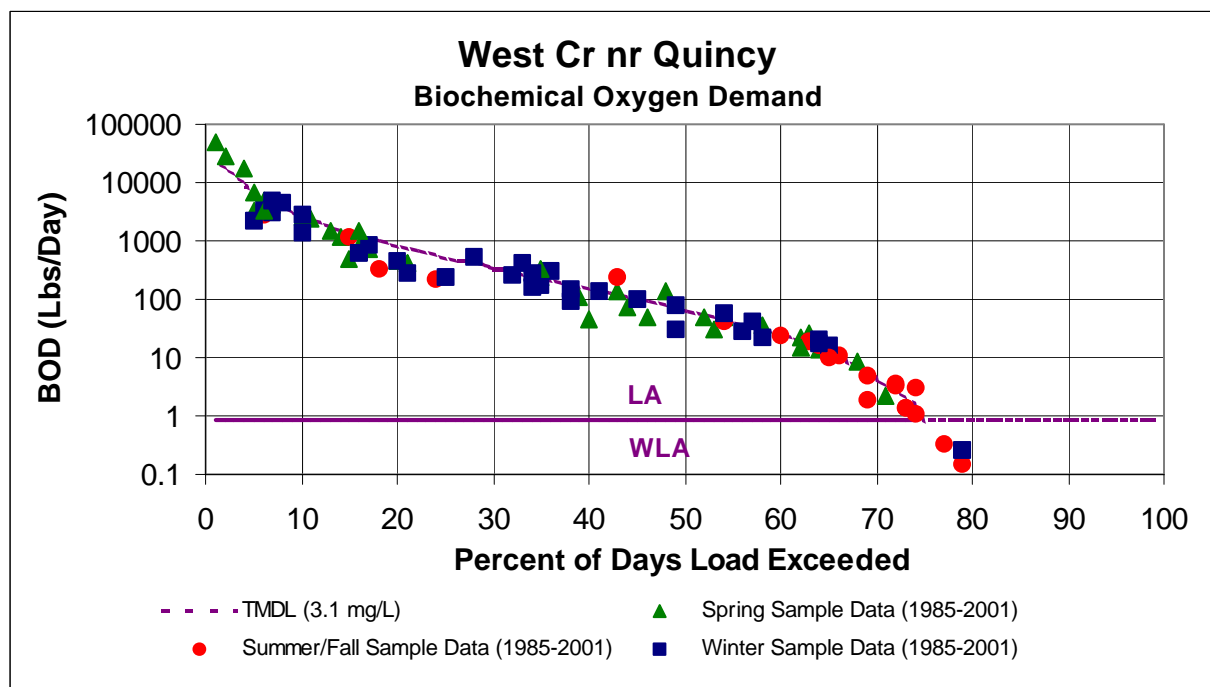
This is a phased TMDL. Additional monitoring over time will be needed to further ascertain the relationship between enhancements in stream restoration and tributary buffer strip conditions which should filter sediment before reaching the stream, reduce sediment oxygen demand and consequently improve DO levels during the critical flow periods of concern. In Phase One of this TMDL the following allocations apply:

**Point Sources:** Point sources are responsible for maintaining their systems in proper working condition and appropriate capacity to handle anticipated wasteloads of their respective populations. The State and NPDES permits will continue to be issued on 5 year intervals, with inspection and monitoring requirements and conditional limits on the quality of effluent released from these facilities. Ongoing inspections and monitoring of the systems will be made to ensure that minimal contributions have been made by this source.

Because of the indications that low flow is the primary factor causing the occasional excursion from the water quality standard rather than BOD, point sources are not seen as a significant source of DO excursions. Streeter-Phelps analysis (attached) indicates the present BOD permit limit (30 mg/L) for the point source maintains DO levels above 5 mg/L in the stream when there is no flow upstream of the discharge point (see attached Streeter-Phelps analysis) and is therefore assumed to correspond to maintaining the historical average BOD concentration of 3.1 mg/L or less at monitoring site 290 across the defined flow condition and achieves the Kansas Water Quality Standard for DO of 5 mg/L.

The design flow of the point source (0.05 cfs) redefines the lowest flow seen at site 290 (75 - 99% exceedance), and the WLA equals the TMDL curve across this flow condition (**Figure 6**).

From this, the WLA for the city of Hamilton is 8.2 lbs/day BOD which translates to an in stream WLA of 0.85 lbs/day BOD at Site 290 (**Figure 6**).



**Figure 6**

**Non-Point Sources:** Again, because the indications that low flow is the driving factor causing the occasional excursion from the water quality standard rather than BOD, non-point sources are also not seen as a significant source of DO excursion in the watershed. The Load Allocation assigns responsibility for maintaining the historical average in-stream BOD levels at site 290 to 3.1 mg/L for flows greater than 0.05 cfs (0-74% exceedance). The LA equals zero for flows from 0 - 0.05 cfs (75 - 99 % exceedance), since the flow at this condition is entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.05 cfs. (**Figure 6**).

To address any artificial sources factoring into the DO violations outlined in **Table 4 of the Appendix** at water quality sampling site 290, buffer strips should be installed on directly contributing tributaries to filter sediment before reaching the stream.

**Defined Margin of Safety:** The Margin of Safety will be implied based on conservative assumptions used in the permitting of the point source discharges including coincidence of low flow with maximum discharge from the treatment plant, associated CBOD content, temperature of the effluent, higher than expected stream velocity and the better than permitted performance of the treatment plant in producing effluent with BOD well below permit limits under critical seasonal conditions. Additionally, the target BOD concentration has been set at a conservative value since sampling data indicates exceeding this value has seldom led to a dissolved oxygen violation.

**State Water Plan Implementation Priority:** Because this watershed has indicated some problem with dissolved oxygen which has short term and immediate consequences for aquatic life, this TMDL will be a High Priority for implementation.

**Unified Watershed Assessment Priority Ranking:** This watershed lies within the Upper Verdigris Basin (HUC 8: 11070101) with a priority ranking of 57 (Low Priority for restoration work).

**Priority HUC 11s and Stream Segments:** Priority should be directed toward baseflow gaining stream segments along the main stem of West Creek (17).

## **5. IMPLEMENTATION**

### **Desired Implementation Activities**

1. Conduct stream morphology review
2. Where needed, create/restore buffer strips along contributing tributaries.

### **Implementation Programs Guidance**

#### **Stream Restoration Program - SCC**

- a. Conduct a stream morphology evaluation along the stream reaches in the vicinity of the monitoring station.
- b. Assess the degree to which sediment is altering stream flow patterns in the channel, including reducing slopes and aeration capability along the stream bed.
- c. Ascertain probable sources of sediment deposition in stream, should it be a primary factor in influencing stream aeration or exerting oxygen demand.
- d. Plan, design and install stream restoration measures which will restore stream flow conveyance and sediment transport capability to the target stream reaches.

#### **Buffer Initiative Program - SCC**

- a. Install grass buffer strips near streams.

**Timeframe for Implementation:** Stream morphology assessments/restoration measures and buffer strips should be installed on main stream and baseflow gaining tributaries over the years 2003-2007.

**Targeted Participants:** Primary participants for implementation will be landowners immediately adjacent to the listed stream segments. Implemented activities should be targeted to those stream segments with greatest potential contribution to baseflow. Nominally, this would be most likely be :

1. Unbuffered cropland adjacent to contributing tributaries.
2. Unstable stream banks and modified channels.

Some inventory of local needs should be conducted in 2003 to identify such activities. Such an inventory would be done by local program managers with appropriate assistance by commodity representatives and state program staff in order to direct state assistance programs to the principal activities influencing the quality of the streams in the watershed during the implementation period of this TMDL.

**Milestone for 2007:** The year 2007 marks the mid-point of the ten year implementation window for the watershed. At that point in time, milestones should be reached which will have at least two-thirds of the landowners responsible for buffer strip restoration or stream restoration measures, cited in the local assessment, participating in the implementation programs provided by the state.

**Delivery Agents:** The primary delivery agents for program participation will be the conservation districts for programs of the State Conservation Commission and the Natural Resources Conservation Service. Producer outreach and awareness will be delivered by Kansas State County staff managing.

**Reasonable Assurances:**

**Authorities:** The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.
2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.
3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including areas where buffer strips may be needed.
5. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.
6. K.S.A. 82a-901, *et seq.* empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.
7. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*.
8. The *Kansas Water Plan* and the Verdigris Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

**Funding:** The State Water Plan Fund, annually generates \$16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This TMDL is a High Priority consideration.

**Effectiveness:** Buffer strips are touted as a means to filter sediment before it reaches a stream and riparian restoration projects have been acclaimed as a significant means of stream bank stabilization. The key to effectiveness is participation within a finite subwatershed to direct resources to the activities influencing water quality. The milestones established under this TMDL are intended to gauge the level of participation in those programs implementing this TMDL.

Should participation significantly lag below expectations over the next five years or monitoring indicates lack of progress in improving water quality conditions from those seen over 1990-2000, the state may employ more stringent conditions on agricultural producers and urban runoff in the watershed in order to meet the desired endpoints expressed in this TMDL. The state has the authority to impose conditions on activities with a significant potential to pollute the waters of the state under K.S.A. 65-171. If overall water quality conditions in the watershed deteriorate, a Critical Water Quality Management Area may be proposed for the watershed, in response.

## 6. MONITORING

KDHE will continue to collect bimonthly samples at Station 290, including dissolved oxygen samples, in order to assess progress and success in implementing this TMDL toward reaching its endpoint. Should impaired status remain, the desired endpoints under this TMDL may be refined and more intensive sampling may need to be conducted under specified seasonal flow conditions

over the period 2007-2011. Use of the real time flow data available at the Otter Creek at Climax stream gaging station can direct these sampling efforts.

A stream restoration review will be conducted in 2004 by the State Conservation Commission to evaluate West Creek in terms of morphology and sediment impacts on stream flow patterns and its effect on aeration within the stream as outlined in the implementation guidance.

Local program management needs to identify its targeted participants of state assistance programs for implementing this TMDL. This information should be collected in 2003 in order to support appropriate implementation projects.

## **7. FEEDBACK**

**Public Meetings:** Public meetings to discuss TMDLs in the Verdigris Basin were held January 23 in Fredonia and March 6, 2002 in Neodesha. An active Internet Web site was established at <http://www.kdhe.state.ks.us/tmdl/> to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Verdigris Basin.

**Public Hearing:** A Public Hearing on the TMDLs of the Verdigris Basin was held in Neodesha on June 4, 2002.

**Basin Advisory Committee:** The Verdigris Basin Advisory Committee met to discuss the TMDLs in the basin on October 3, 2001, January 23 and March 6, 2002.

**Milestone Evaluation:** In 2007, evaluation will be made as to the degree of impairment which has occurred within the watershed and current condition of West Creek. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

**Consideration for 303(d) Delisting:** The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2007-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

**Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process:** Under the current version of the Continuing Planning Process, the next anticipated revision will come in 2003 which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2003-2007.

Appendix (West Creek DO TMDL)

Table 2					
West Cr Wtrshd (290)			Otter Creek Wtrshd (574)		
Land Use	Acres	% of Total	Land Use	Acres	% of Total
Cropland	3915	5.0	Cropland	4394	5.6
Grassland	71591	90.8	Grassland	69690	89.1
Urban Use	139	0.2	Urban Use	0	0.0
Water	581	0.7	Water	609	0.8
Woodland	2651	3.4	Woodland	3496	4.5
Total	78879	100	Total	78190	100

Table 3																					
COL_DATE	DISOXY		AMMONIA		BOD		FECCOLI		NITRATE		PHFIELD		TEMP_CENT		PHOSPHU		TSS		TURBIDITY		Flow (est.)
	290	574	290	574	290	574	290	574	290	574	290	574	290	574	290	574	290	574	290	574	
4/11/90	9.1	9.7	0.010	0.010	1.80	0.01	100	200	0.11	0.23	8.1	8.1	11	11	0.030	0.020	30	17	8.4	8.4	48.000
6/13/90	6.0	6.0	0.030	0.000	2.00	2.10	700	400	0.48	0.43	7.9	8.1	24	25	0.090	0.050	80	52	49.4	25.2	9.840
8/15/90	6.0	7.0	0.060	0.010	2.00	3.00	700	180	0.24	0.18	7.7	8.1	22	22	0.110	0.060	66	31	54.7	19.6	0.125
10/10/90	6.5	7.8	0.020	0.030	1.90	3.10	250	60	0.28	0.03	7.8	8.0	11	11	0.050	0.030	11	14	8.1	12.0	0.001
12/5/90	9.6	10.7	0.000	0.000	1.80	2.90	380	10	0.10	0.00	8.1	8.3	3	2	0.020	0.020	6	5	2.7	3.7	0.001
3/13/91	8.9	9.2	0.020	0.020	4.50	3.20	10	10	0.01	0.02	8.1	8.2	6	7	0.030	0.030	15	17	8.2	10.4	0.001
5/15/91	4.7	6.3	0.000	0.000	3.60	4.70	320	80	0.03	0.04	7.9	8.1	22	22	0.060	0.070	24	33	15.1	19.0	0.432
7/31/91	4.3	5.0	0.000	0.000	2.40	4.40	400	100	0.06	0.24	7.9	7.9	24	24	0.060	0.110	20	51	10.4	36.9	0.001
9/11/91	3.9	4.2	0.000	0.000	3.30	2.80	22000	100	0.11	0.11	8.0	7.9	26	25	0.060	0.060	17	17	13.0	12.1	0.001
2/12/92	11.8	11.3	0.000	0.000	3.10	2.50	1000	70	0.05	0.13	8.0	8.1	2	3	0.050	0.050	14	13	7.0	7.9	6.000
4/15/92	7.7	7.6	0.050	0.050	2.10	2.00	70	100	0.02	0.03	8.2	8.2	17	19	0.050	0.050	23	19	12.7	12.0	6.600
6/10/92	6.8	6.5	0.050	0.050	5.10	6.20	7000	25000	0.24	0.42	6.8	7.7	19	19	0.460	0.800	682	976	338.0	464.0	1059.000
8/5/92	6.3	6.9	0.050	0.050	2.70	2.20	3000	1800	0.08	0.26	7.9	7.9	20	20	0.160	0.150	151	96	82.0	58.6	78.000
10/7/92	7.4	8.0	0.050	0.050	3.10	2.46	90	100	0.02	0.14	8.1	7.9	15	15	0.050	0.050	21	21	10.5	9.3	1.440
12/9/92	12.9	12.2	0.050	0.050	2.20	1.70	1200	100	0.38	0.54	-----	-----	0	2	0.050	0.050	24	27	21.0	20.0	307.200
3/10/93	11.0	10.8	0.050	0.050	1.70	1.10	100	30	0.32	0.38	8.1	8.2	7	7	0.050	0.050	21	19	8.0	5.0	66.000
5/5/93	8.3	8.6	0.050	0.050	2.00	1.20	700	460	0.24	0.42	7.9	8.0	15	15	0.110	0.060	56	76	42.0	26.0	307.200
7/14/93	6.7	6.6	0.050	0.050	3.30	3.60	810	60000	0.49	0.56	8.2	8.0	24	24	0.070	0.190	20	88	18.0	29.0	130.800
9/15/93	6.5	7.6	0.050	0.050	2.70	1.70	200	100	0.24	0.67	7.9	7.9	15	15	0.080	0.080	21	20	12.0	10.0	0.336
11/10/93	6.7	9.6	0.050	0.050	5.00	4.00	10	10	0.05	0.27	7.5	7.7	4	4	0.080	0.050	10	11	6.0	4.0	16.080
4/13/94	10.0	10.3	0.050	0.050	4.10	3.30	3800	1500	0.39	0.39	7.9	7.9	8	7	0.150	0.070	112	62	66.0	34.0	307.200
6/14/94	6.6	6.8	0.050	0.050	3.70	3.20	400	2300	0.02	0.29	8.1	8.0	24	23	0.050	0.050	22	22	11.0	8.0	1.824
8/10/94	3.4	7.6	0.010	0.010	6.50	9.40	200	400	0.01	0.11	7.8	8.0	24	23	0.090	0.080	34	34	11.0	9.0	0.086
10/12/94	2.9	5.8	0.010	0.010	3.10	3.30	600	500	0.01	0.01	7.5	7.8	12	12	0.010	0.010	10	17	5.0	7.0	0.001
12/7/94	9.0	10.5	0.060	0.060	3.90	3.90	300	20	0.34	0.40	7.7	7.9	3	2	0.060	0.010	24	9	18.0	4.0	2.016
1/19/95	12.0	11.9	0.010	0.010	4.50	1.70	10	100	0.04	0.17	8.0	8.1	2	2	0.010	0.010	4	2	2.0	2.0	0.864
3/22/95	9.6	8.9	0.010	0.010	2.50	1.40	60	100	0.10	0.17	8.1	8.1	15	14	0.050	0.040	26	22	13.0	6.0	10.680
5/17/95	8.3	8.0	0.120	0.120	6.90	7.60	60000	60000	0.16	0.25	7.8	7.6	16	17	0.990	1.410	1410	1360	195.0	157.0	1296.000
7/19/95	6.2	6.8	0.010	0.010	2.70	2.40	10	100	0.09	0.34	7.9	7.9	24	24	0.050	0.060	28	31	5.0	13.0	3.264
9/20/95	5.5	7.5	0.310	0.230	2.70	2.00	200	500	0.23	0.55	7.8	7.9	17	17	0.060	0.041	33	22	8.0	8.0	0.720
11/15/95	7.0	11.4	0.030	0.036	3.70	1.20	100	10	0.01	0.15	7.8	7.8	4	5	0.040	0.013	8	7	2.0	2.0	0.864
2/21/96	14.2	11.5	0.060	0.054	4.00	3.20	4	1	0.11	0.25	7.8	7.7	4	4	0.040	0.035	15	15	8.8	6.1	0.001
4/17/96	8.0	10.0	0.080	0.028	3.80	5.10	1	100	0.04	0.06	8.1	8.1	14	12	0.040	0.030	16	18	9.0	5.0	0.001
6/19/96	3.2	4.8	0.160	0.083	2.90	3.30	320	1000	0.11	0.26	7.5	7.6	23	22	0.090	0.208	41	128	21.0	96.0	0.864
8/14/96	3.1	9.6	0.240	0.120	4.60	7.50	10	50	0.09	0.01	7.6	8.1	22	22	0.132	0.095	32	38	14.0	14.0	0.001
10/9/96	7.0	7.8	0.340	0.308	6.20	6.00	310	300	0.09	0.08	7.8	8.0	13	14	0.110	0.070	48	37	33.0	17.0	7.200
12/4/96	13.1	13.0	0.020	0.020	3.80	3.10	1400	400	0.22	0.26	8.1	8.0	3	4	0.110	0.078	68	20	47.0	30.0	225.600
1/8/97	12.4	12.6	0.020	0.020	1.29	1.00	10	50	0.07	0.15	8.1	8.0	3	4	0.010	0.012	1	2	1.9	2.7	4.272
3/5/97	11.8	11.3	0.020	0.020	1.62	1.00	60	30	0.28	0.32	8.0	7.9	7	6	0.050	0.020	22	10	18.0	5.0	72.000
5/7/97	7.6	8.4	0.020	0.020	4.44	2.16	300	40	0.04	0.19	7.8	7.9	18	18	0.010	0.010	13	8	5.4	3.3	13.200
7/9/97	6.9	6.2	0.020	0.020	2.85	2.91	19000	2300	0.31	0.13	7.6	7.8	23	25	0.340	0.319	484	260	270.0	86.0	266.400
9/10/97	6.3	6.8	0.020	0.020	2.10	1.14	70	300	0.07	0.25	7.9	7.7	22	22	0.080	0.050	28	15	28.0	13.0	0.029
11/5/97	5.6	8.2	0.020	0.020	4.47	2.67	20	110	0.01	0.11	7.4	7.8	9	9	0.090	0.060	12	11	7.9	5.4	0.011
2/4/98	11.8	11.7	0.020	0.020	1.59	1.08	20	20	0.28	0.17	8.1	8.1	4	4	0.010	0.010	16	7	7.7	3.4	10.680
4/8/98	9.8	9.9	0.020	0.020	2.01	1.35	190	390	0.09	0.16	8.2	8.1	12	13	0.047	0.034	24	19	16.0	10.0	72.000
6/3/98	6.7	7.9	0.020	0.020	1.89	1.32	130	230	0.01	0.24	7.8	7.9	26	26	0.050	0.050	19	20	9.7	9.0	2.976
8/5/98	4.7	4.9	0.020	0.030	2.61	1.77	1000	1300	0.33	0.39	7.6	7.7	25	25	0.140	0.100	58	46	48.0	32.0	0.720
10/7/98	8.4	7.8	0.020	0.020	1.00	1.26	440	390	0.22	0.34	7.8	7.9	17	17	0.092	0.067	46	34	30.0	21.0	60.000
12/9/98	10.8	11.0	0.020	0.020	3.75	3.90	6600	2100	0.25	0.39	7.8	7.8	7	8	0.090	0.050	25	15	24.0	9.0	144.000
3/1/99	11.9	10.8	0.030	0.040	3.48	2.34	10	30	0.05	0.23	8.0	8.0	10	11	0.040	0.030	18	8	7.9	3.0	14.640
5/3/99	8.3	8.8	0.020	0.020	1.29	1.00	110	180	0.40	0.34	7.9	8.1	18	18	0.050	0.030	18	11	10.7	5.0	72.000
6/28/99	5.9	6.9	0.020	0.020	2.04	1.71	4900	3700	0.32	0.55	7.7	7.9	26	25	0.100	0.140	63	114	43.0	55.0	307.200
8/30/99	4.7	7.3	0.020	0.020	1.00	1.00	20	30	0.21	0.35	7.5	7.7	26	26	0.040	0.040	19	20	9.0	9.0	0.336
11/1/99	4.9	6.5	0.191	0.020	4.08	3.72	90	2400	0.03	0.06	7.6	7.8	15	16	0.083	0.074	13	12	6		

# **Streeter-Phelps DO Sag Model - WestCrDO\_Hamilton** **Single Reach (West Creek) - Single Load**

1 cfs = .0283 m<sup>3</sup>/s  
0.25 mph = 0.11176 m/s

	Elev (ft)	Dist to 290	Min DO	Crit Dist DO
0.0014331 Design Flow (Hamilton)	1060	28.90	5.49	8.82

## **Elevation Correction (DO)**

Elevation	<b>1060</b> ft
Correctn Factor (DO <sub>sat</sub> )	<b>0.96608</b> mg/L

Distance (km)

Flow (m<sup>3</sup>/s)

Concentration (mg/L)

Temp ( C )

Vel (m/s)

Unless modified by upstream pt. source, upstream BOD set as target for basin

Upstream DO (where appropriate) elevation corrected and set at 90% sat.

Velocity	0.11176		
BOD coef	0.23	Theta	1.056
O2 coef	1.92	Theta	1.024

	Flow	BOD	DO	T	Dist	Slope (ft.mi)	Calc K <sub>r</sub>	
1 <b>Hamilton</b>	0.0014331	30	6.86	21.7	28.9	7.29	1.92	
Upstream	0	0	0	0	-----			
Result at Dist (Site 290)	0.0014331	14.1	6.47	23.3				Elev = 929 ft

**Kr Values (Foree 1977) using** 0.42 (0.63 + 0.4S<sup>1.15</sup>)  
for q < 0.05 where q = cfs/mi<sup>2</sup> and S (ft/mile)

